

# **APPLICATION OF COMPUTER TOMOGRAPHY (CT) FOR SEARCH OF LIFE IN EXTREME ENVIRONMENTS**

A. Tsapin, M. Storrie-Lombardy, G. McDonald, and K. Neelson

Jet Propulsion Laboratory/California Institute of Technology, MS 183-301,  
4800 Oak Grove Dr., Pasadena, CA 91109

J. Nesson

Arcadia Radiology Medical Group, 612 W. Duarte Rd., Suite 101, Arcadia, CA  
91007

## **1. Introduction**

of First attempts to find life outside the Earth were made after the Apollo missions brought back lunar rocks. In 2008 we expect to work with Martian rocks. The search for signs of extraterrestrial life in the Universe is one of the most ambitious projects in human history. To meet this challenge we have to be able to recognize the presence of life or its remnants inside rocks or soil samples. In the last 30-40 years, a significant number of studies were done on endolithic organisms. These organisms were found in rocks in Dry Valley (Antarctica), and in rocks in mines at different depths up to several km. In order to study endolithic microorganisms, we need efficient methods that would enable us to visualize them inside their natural habitats -- rocks.

There is a need to develop an effective nondestructive and non-invasive technique that would allow identification of life or life signatures in Martian samples. In order to be able to detect bacteria and/or biofilms of 10-200  $\mu\text{m}$ , the technique must have the appropriate resolution. A technique of this kind could be used for other applications such as early diagnosis of bacterial infections of bone tissues, detection of bacterial components in materials used for storage of nuclear wastes, monitoring of bacterial contamination in hospitals and medical tools, and many other such programs.

A prospective analysis of the incoming Martian materials will require a large database of known samples from a variety of worldwide environments, which, in turn, requires state of the art CT equipment designed primarily for this research.

In this study we propose to use computer tomography (CT) for these purposes. The method of CT is based on interaction of X-rays with nuclei of atoms in the sample. The information obtained as a result of CT experiments reflects the spatial distribution of sample density. In some cases, it is possible to locate biofilms and the areas inside rocks colonized by microorganisms (Torres 1999). Indeed, we have been able to map layers of algae, lichens and fungi inside of rocks from Antarctic Dry Valley. The CT data have been supported with optical and electron microscopy studies. Currently we are in the process of improving this technique in order to achieve a better spatial resolution, which

is now about 300 – 500 micron. We have successfully applied CT for imaging of the soil samples from desert environments (Death Valley).

## **2. Using X-ray computer tomography (CT) for imaging biological systems inside rocks.**

Only 20-30 years ago the postulate that life could exist only under very narrow set of conditions such as temperature, pH, pressure, etc, was generally recognized as an axiom. This notion started to erode after the discovery of microorganisms capable ~~to live~~ *of living* at temperatures above 100° C. In fact, now it is difficult and perhaps even impossible to find an environment on the Earth, (loosely called the extreme environment), uninhabited by microorganisms. Microorganisms have proved that they are able to adapt to almost any conditions, as long as the environment can provide a source of free energy.

Astrobiology is facing a challenging problem of determining whether or not life exists or ever existed on Mars. Samples obtained from Mars will be instrumental for such a study. Discoveries of microorganisms in permafrost samples several hundred thousand years old, in deep oil fields and mines as well as endolithic bacteria require new technologies that should be able to detect life or remnants of life in samples from different environments, including samples from Mars, without disturbing them. This task will require development of a comprehensive, non-invasive technique.

CT, an imaging tool combining a computer with an X-ray device, should be used as the first method for analysis of non-transparent specimen. The analyzed object is positioned between an X-ray tube and a detector array (gantry). A beam of X-rays penetrates the object as the tube and detectors rotate at 360 degrees (Kalender & Polacin 1991). The newest generation of CT scanners has added a spiral motion providing continuous rotation and data acquisition. During this rotation the couch supporting the object moves through the plane of X-rays at a set speed relative to the rotational speed of the gantry. The quantity of X-rays absorbed by any given point within the object (pixel) is then calculated using back-projection algorithms, and relative density (brightness) is assigned to the pixel (brighter = more dense, darker = less dense). The composite of these pixel densities produces a 2-D image of the internal structure of the object according to its X-ray absorption properties (Herman 1980). The thickness of the slice is preset prior to scanning. Post-processing can then stack these slices to produce a 3-D rendition of the object (Napel et al. 1992). Rotation of the 3-D image provides for perception of the three dimensional relationships of the internal structure. Density ranges within the object can be emphasized in the post-processing with the addition of color to a specific density range.

**Windowing.** CT X-ray density measurements range from -3,000 (air) through 0 (water) to +3,000 (very dense). The human body has a CT density range starting below 0 with fat and extending up to about 300 for dense bone. Dense rock and metal lie above 3,000 and can reach as high as 10,000. The cathode ray tube (CRT) display is set to view the image over a range of CT densities (window width) centered at one density point (level). Proper window level and width settings are critical for image display. High-density

objects present particular problems in imaging and are best suited to study using the newest generation of CT scanner.

**Paleontology.** CT noninvasive imaging of fossils allows displaying the internal structure without altering the specimen. Fossilization of an organism's hard and soft tissues through mineral replacement results in subtle differences in X-ray absorption between the structure and the surrounding inorganic matrix. CT is able to depict these subtle differences. Any internal structure of a fossil can be mapped using the coordinates of the CT scan. This provides the opportunity to extract and examine desired portions of the fossil with minimal invasion.

The CT scanning of Cambrian fossils with circular surface imprints (*Spriggia*) has shown an attached stalk. In fact, there is no other way to display the fossilized stalk and thus demonstrate that the circular surface pattern represents the holdfast of a stalked organism rather than a free floating jellyfish type. This may be the only way of noninvasive study of non-skeletonized Cambrian or Pre-Cambrian organisms. As CT resolution increases, it will provide the means for studies of ancient multi-cellular organisms, thus advancing the understanding of their evolution.

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